DAHLGREN DIVISION
NAVAL SURFACE WARFARE CENTER
Dahlgren, Virginia 22448-5100

NSWCDD/TR-97/25

NASA BOEING 757 CAVITY FIELD VARIABILITY BASED ON BOEING 757 AND BOEING 707 TEST DATA

BY MICHAEL O. HATFIELD D. MARK JOHNSON
(NSWCDD)

GUSTAV J. FREYER
(NORTHEAST CONSORTIUM FOR ENGINEERING EDUCATION)

MICHAEL B. SLOCUM
(COMPUTER SCIENCES CORPORATION)

SHIP DEFENSE SYSTEMS DEPARTMENT

JANUARY 1997

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1997	Final

4. TITLE AND SUBTITLE

NASA Boeing 757 Cavity Field Variability Based on Boeing 757 and Boeing 707 Test Data

5. FUNDING NUMBERS

6. AUTHOR(s)

Michael O. Hatfield, D. Mark Johnson, Gustav J. Freyer, Michael B. Slocum

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Commander
Naval Surface Warfare Center
Dahlgren Division (Code J52)
17320 Dahlgren Road
Dahlgren, VA 22448-5100

8. PERFORMING ORGANIZATION REPORT NUMBER

NSWCDD/TR-97/25

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The NASA Langley Research Center conducted an extensive ground and flight test program to validate detailed modeling of the Boeing 757 aircraft. Most of the ground and flight test data were obtained using D-dot probes in fixed locations in the cockpit, electronics bay, and passenger cabin.

An open question was the uncertainties that may be expected for the comparison of experimental measurements and model predictions.

The Naval Surface Warfare Center, Dahlgren Division and the USAF Phillips Laboratory had performed cavity characterization tests on the same Boeing 757 as used for the flight tests. Extensive cavity characterization data was also available for a Boeing 707 aircraft. While the three specific flight test comparison frequencies were not investigated in these tests, sufficient data were available to provide estimates of the expected uncertainties. Some of the data in the cavity characterization tests were collected with the flight test D-dot probes in the same locations.

A summary of the results is presented as a standard deviation in decibels in a series of tables for each cavity and each frequency.

14. SUBJECT TERMS	15. NUMBER OF PAGES
cavity characterization, electromagnetics, Boeing 757 aircraft, flight test, D-dot probes, modal structure	30
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORTS	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

FOREWORD

The analyses presented in this report were conducted by the Systems Electromagnetic Effects Branch (J52), Electromagnetic Effects Division of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD). The work was funded by the NASA Langley Research Center, Langley, VA.

The analyses were performed on available Boeing 757 and Boeing 707 cavity characterization data obtained in four test sequences by the NSWCDD and the USAF Phillips Laboratory, Albuquerque, NM.

The authors wish to acknowledge Major T. A. Loughry (formerly of USAF Phillips Laboratory) for the use of the data he collected using the Band Limited White Gaussian Noise excitation technique.

This report has been reviewed by William Lucado, Head, Systems Electromagnetic Effects Branch, and Leonard Fontenot, Head, Electromagnetic Effects Division, and Dr. Lisle H. Russell, Chief Scientist, Joint Warfare Applications Department.

Approved by:

CHARLES E. GALLAHER, Head
Joint Warfare Applications Department

CONTENTS

ILLUSTRATIONS

TABLES

OBJECTIVE

To provide an estimate of the expected cavity field variability derived from B757 and B707 cavity electromagnetic characterization measurements as a reference for comparison of model and measured data from the NASA B757 flight test program.

BACKGROUND

Measurements obtained during the NASA B757 cavity characterization tests provide a data base from which estimates of cavity field measurement uncertainties can be derived. An extensive data base also exists for cavity characterization tests of a B707 aircraft. These data can be used to supplement the B757 data base.

The variability in the measured field strength at an arbitrary point in a cavity depends on the effective modal structure. The effective modal structure includes the cavity quality factor, Q, effects which result in averaging over the number of distinct modes within the Q bandwidth, BW_Q. Appendix A has a short discussion of the effective modal structure.

For fixed boundary conditions the field will vary spatially as the effective modal structure varies with position. This variability should not be a major factor for measurements at the well-defined D-dot probe locations. However since, in most cases, data are not available at the D-dot probe locations, the added uncertainty in the derived estimates due to extrapolation of measurements from other locations is included in the analysis. The spatial uncertainties are designated in the analysis as "measurement location effects".

Another source of field variability is due to changes in the modal structure as the cavity boundary conditions change. Any change in cavity boundary conditions will result in changes in the effective modal structure. Boundary conditions vary with the number and location of crew, test instrumentation and cables, and the number and location of a wide variety of conducting or partially conducting objects. Boundary condition effects can be quantified by observing the field variability at a fixed location while mode-mixing within the cavity. The uncertainties are designated in the analysis as "boundary condition effects".

A third source of uncertainty is the effectiveness of exciting the modal structure. For internal excitation measurements this can be investigated through multiple measurements where the excitation source location is varied. These measurements are limited in the data base. When data are available they are included in the location uncertainty analysis.

The ideal data base for the determination of the field strength variations would be a set of stirring ratio (SR) data measured by the D-dot probes at each of the frequencies of interest. Unfortunately there are no SR measurements in the B757 at the three frequencies of interest. Therefore the estimates of field variations had to be based on extrapolations of several types of data from frequencies at which data were available.

Stirring ratio data for the B707 at 100 MHz is shown in Figure 1. The SR is the ratio of the maximum received power to the minimum received power as the tuner rotates at a fixed cavity excitation frequency. The tuner rotation time is approximately 5.8 seconds after which the pattern repeats out to the total sampling time of 7 seconds. The maximum to minimum boundary condition effect implied from Figure 1 is 17 dB. At frequencies where the cavity is sufficiently multi-moded and the tuner dimensions are on the order of a wavelength or greater, it has been shown that the distribution of received power bounds the electromagnetic environment (EME) in the cavity for a variety of cavity boundary conditions.[1*] A SR measurement yields the maximum, minimum, average, and standard deviation (SD) of the power density variations possible at the location of the receive antenna in the cavity. A series of SR measurements at different locations within the cavity could be used to estimate the field variations due to measurement location effects.

A data base from both B757 and B707 cavity characterization tests exists from which the variability of the calculated/measured fields due to boundary condition and measurement location effects can be estimated. The frequencies of interest are 0.173, 0.430, and 5.4 GHz. Where B757 data were available, they took precedence in the analysis.

For a variety of reasons the B757 Phase I (Band Limited White Gaussian Noise (BLWGN) excitation[2]) data was limited to 0.5 - 6.0 GHz and the Phase II (continuous wave (CW) excitation with mechanical mode mixing) data were limited to 0.8 - 6.0 GHz.

Only a limited analysis of the available B757 Phase I and II data has been performed to date.

The B707 Phase I (CW excitation with mechanical mode-mixing) and Phase II (CW and BLWGN excitations) data should be representative of the variability expected in the B757. Detailed analyses of the B707 Phase I and II data have been performed.[1,3] However the analyses did not address the specific details desired for the comparison of computer model predictions and the measured flight data.

APPROACH

The existing Naval Surface Warfare Center, Dahlgren Division (NSWCDD) and USAF Phillips Laboratory (PL) B757 and B707 data bases were reviewed. All measurements which could contribute to an estimate of the field variability to be expected in the B757 cockpit, electronics bay,

---

*Superscripts refer to references at end of main text, p. 19.

and passenger cabin were identified. The list included 96 B757 measurements and 104 B707 measurements. The measurements were grouped according to the type of data. For boundary condition effects, the primary data type was SR. For measurement location effects estimates, the primary data type was multiple insertion loss (IL) data.

BOUNDARY CONDITION EFFECTS

No low frequency (below 0.8 GHz) SR data were available for the B757. Estimates of the field variability due to boundary condition effects were therefore obtained from the SR data from the B707 for the cockpit, electronics bay, and passenger cabin. At low frequencies (typically 500 MHz and below for aircraft cockpits and electronics bays) a combination of the modal structure and the tuner effectiveness determine the observed variations.

The SD of the B707 cockpit data at 100 MHz in Figure 1 is 4.5 dB.

Between 100 and 500 MHz a SR data base from the Phase I and II tests exists for defining the boundary condition effects for the B707 cockpit (36 measurements), electronics bay (48 measurements), and passenger cabin (4 measurements). The SR data base was reviewed and used to estimate the SD at 100, 200, 300, 400, and 500 MHz in each cavity.

Also available for each B707 cavity were frequency scans without the tuner in operation. The cockpit data is shown in Figure 2. Since these data are continuous across 100 - 500 MHz, they can be used to estimate the SD at the frequencies of interest. The technique for using the frequency scan data will be discussed in the Results Section.

Since the B707 cockpit and electronics bay are larger than the B757 cockpit and electronics bay, the B707 data should be an upper bound on the boundary condition effects variations expected in these cavities in the B757. This follows from the reduced number of modes at a given frequency in the smaller cavity as well as a smaller tuner with the resulting decreased effectiveness in providing boundary condition changes.

At high frequencies there is a SR data base at 4.0, 4.1, 5.99, and 6.0 GHz for all three B757 cavities. Figure 3 shows SR data at 4.00 GHz in the B757 cockpit. There is some noise contamination as evidenced by the deep nulls. Much of the data above 4 GHz has noise contamination.

To remove the noise contamination, the lowest 1% of the data was ignored as indicated by the dashed line in Figure 3. From Figure 3 the field maximum variability due to possible changes in cockpit boundary conditions is at least 28 dB at 4 GHz. A SD of 4.2 dB was calculated for the noise corrected data.

To avoid the large extrapolation to 5.4 GHz from the available SR data, an additional type of measurement was included in the analysis. To investigate the modal structure in the B757 cavities, a set of data was collected with constant boundary condition (no mode-mixing) frequency scans. These data over the frequency range 4 - 6 GHz in the cockpit are shown in Figure 4. If the frequency

sampling interval is small enough, the modal structure as a function of frequency can be determined. A single frequency scan gives an indication of the modal structure variability but does not provide a bound on the variation. By combining multiple frequency scans (obtained after changing the boundary conditions between scans) which cover the 4 - 6 GHz frequency interval with SR data at the end points, it was possible to estimate the boundary condition effects variations at 5.4 GHz for each of the cavities.

The general approach to boundary condition effects was to review all data which could contribute to estimates of the frequencies of interest. The results are best engineering judgments with uncertainties stated in terms of the estimated standard deviation.

MEASUREMENT LOCATION EFFECTS

Multiple IL data measurements were used to obtain an estimate of the field variations due to non-uniformity of the cavity EME. Figure 5 shows the received power as a function of frequency for a specific configuration of the transmit (TX) and receive (RX) antennas in the cockpit. These data were obtained using BLWGN for mode excitation. The technique excites the modal structure over the bandwidth (BW) of the noise, in this case, 50 MHz. As would be expected, the trace is considerably smoother than one obtained with mechanical mode-mixing since the BLWGN technique averages the response over the BW.

The only data in the frequency range 100 - 500 MHz is from the B707. To verify the applicability of these data, the SD of the measurement location effects obtained with BLWGN in both aircraft were compared over the frequency range 0.5 - 1 GHz. The results of the comparison were applied to the 0.2 - 0.5 GHz B707 data to obtain an estimate for 173 and 430 MHz in the B757.

Four BLWGN insertion loss measurements were available for each cavity of the B757 which could be used for a direct estimate of the measurement location effects at 5.4 GHz.

RESULTS

BOUNDARY CONDITION EFFECTS

The SD of the low frequency B707 SR data is summarized as the circular markers in Figures 6, 7, and 8 for the cockpit, electronics bay, and passenger cabin respectively. To use the boundary condition effects data from the frequency scans without the tuner in operation (see Figure 2), an appropriate BW must be selected. The BW selection was based on a comparison to the SR data. At frequencies where SR data were available, the boundary condition effects data were analyzed by calculating the SDs for BWs from 10 to 200 MHz. These were compared to the known SD of the data from the SR data. Reasonably consistent agreement with all the SR data was obtained for a BW of 100 MHz. The modal structure at 173 ± 50 MHz and 430 ± 50 MHz yielded the square markers in Figures 6, 7, and 8. These results are summarized in Table 1. As noted earlier, the

Table 1 values derived from B707 data for the cockpit and electronics bay should be an upper bound for the B757.

The SDs from 4.0, 4.1, 5.99, and 6.0 GHz SR measurements are summarized as the circular markers in Figure 9 for the cockpit. These values are based on noise corrected SR data as discussed in the Approach and as shown in Figure 3. The cockpit modal structure data for 4 - 6 GHz are shown in Figure 4. To estimate the SD from this data, several BWs were investigated to compare with the SD data from SR measurements. The modal structure data also involved noise contamination corrections. The most consistent results were obtained with BWs of 20 MHz. This BW was applied to the modal structure at 5.4 GHz with the 3.8 dB result shown as the square marker in Figure 9 and listed in Table 1.

No SR measurements are available in the B757 electronics bay. However, four frequency scan measurements with the electronics bay D-dot probe are available. These data have the advantage of providing a direct estimate at the D-dot probe location. While not direct measurements of boundary condition effects like SR measurements, frequency scan data can be used to estimate the field variability. A SR measurement could yield a higher SD since it considers a larger sample of boundary condition changes. At 5.4 GHz the SD of these measurements is 4.9 dB. This value is listed in Table 1.

In the passenger cabin there are six IL measurements obtained with the D-dot probe. The SD of these measurements indicate a minimum estimate of the boundary condition effects at the location of the D-dot probes. The suggested minimum SD value for the passenger cabin is 4.5 dB and is listed in Table 1.

MEASUREMENT LOCATION EFFECTS

Figures 10 and 11 show the SD of four BLWGN low frequency measurements as a function of frequency in the B757 and B707 cockpits respectively. While the data show different frequency dependencies, the maximum and average values of the SDs are similar. An average value of about 3 dB was estimated for both aircraft over the frequency interval 0.5 - 1.0 GHz. Maximum values for the B757 and B707 are about 5 and 6 dB respectively. Based on the B707 data, the estimated values for 173 and 430 MHz in the B757 cockpit are given in Table 2.

Figures 12 and 13 show the SDs of four BLWGN measurements in the B757 and B707 electronics bay. The estimated values for the electronics bay uniformity SDs are shown in Table 2.

Figures 14 and 15 show the SDs of four BLWGN measurements in the B757 and B707 passenger cabin. The estimated values for the passenger cabin uniformity SDs are shown in Table 2.

Figure 16 shows the SD over the frequency interval 4 - 6 GHz for the four BLWGN measurements in the B757 cockpit. The variability with frequency is almost 5 dB. The estimate for the average SD at 5.4 GHz is 2.5 dB and 5 dB for the maximum SD. These results are shown in Table 2.

Figures 17 and 18 show the same results for the electronics bay and passenger cabin. The values for the estimated average and maximum SDs at 5.4 GHz for the electronics bay are listed in Table 2.

Note the large implied variability in the passenger cabin in Figure 18. During the B757 Phase II (CW) test an apparent longitudinal gradient in the passenger cabin was noted. Specific measurements were performed to verify and quantify the results. In the Phase I (BLWGN) test this effect was not noted. Although a limited measurement set exists which could contribute to an understanding of the gradient issue, that investigation was beyond the scope of this task. A gradient will primarily effect the average value of measurements taken at various positions along the longitudinal axis of the aircraft. Thus any result based on using average values will be impacted by the gradient. This includes all BLWGN and all CW modal structure data.

Engineering judgment suggests that the SD derived from Figure 18 is an overestimate of the measurement location effects in a limited neighborhood of the NASA D-dot probe in the passenger cabin. Seven CW frequency scan measurements are available in the passenger cabin. The SD of these data, 5.8 dB, suggest a more realistic estimate of average SD for measurement location uncertainty. The average value from the frequency scans and the maximum value from the IL measurements are listed in Table 2 for the passenger cabin.

TOTAL FIELD UNCERTAINTY

The total field variation that could be expected at a single location for a specific cavity boundary condition depends on both the boundary condition effects and the measurement location effects. The SD of the total field variation was assumed to be the root-mean-square of the SD of the boundary condition effects and measurement location effects. The values are given in Table 3.

SUMMARY

An extensive data base was reviewed and several types of data including stirring ratio and insertion loss measurements with and without mechanical mode-mixing from both the B757 and B707 were evaluated. Procedures were developed to extrapolate results from tested frequencies to the desired frequencies.

Field variations at a fixed position due to the boundary condition effects were evaluated and the results specified in terms of a standard deviation. The results presented in Table 1 should be a good estimate of the expected uncertainty between the model and flight test data obtained with the D-dot probes.

At the low frequencies the standard deviation estimates were based on extrapolation of B707 stirring ratio data aided by frequency scans (insertion loss) measurements without mode-mixing.

At 5.4 GHz for the cockpit, the estimate of the standard deviation of the boundary condition effects was based on extrapolation of B757 stirring ratio data aided by frequency scan data.

For the electronics bay and the passenger cabin there were sufficient B757 insertion loss measurements using the D-dot probes to provide a direct estimate of the boundary condition effects.

The standard deviation estimates for the boundary condition effects for the three frequencies of interest are listed in Table 1 for the three cavities. Since the D-dot probes were at the same fixed locations during the Phase I and II tests and the flight tests, the 5.4 GHz results in Table 1 should be particularly reasonable estimates of the uncertainty due to boundary condition differences between the model and the actual aircraft configuration during the flight tests.

The only data directly applicable to estimating the B757 measurement location effects were band limited white gaussian noise insertion loss measurements in all three cavities. These measurements covered the frequency range 0.5 to 6 GHz and therefore did not address the two low frequencies. For the low frequencies, B757 and B707 data were compared in their overlap region. The B707 data were used to deduce an estimate of the measurement location effects at 0.173 and 0.430 GHz. The B757 data yielded the SD of the field uncertainties at 5.4 GHz due to measurement location effects. However for the passenger cabin these measurement yielded an unexpectedly large SD. Based on engineering judgment a more representative estimate for the average SD was obtained from multiple frequency scan measurements.

All measurement location effects are reported as average and maximum SDs in Table 2. The SD values in Table 2 include both measurement location and mode excitation efficiency effects. These data are probably most useful in estimating potential uncertainties due to differences between the actual structure of the aircraft and that assumed in the model.

The total estimated standard deviation of the field uncertainties were calculated as the root-mean-square of the boundary condition effects standard deviation and the measurement location effects standard deviation at each frequency. The results are tabulated in Table 3 for each frequency. These values should provide an upper bound for the uncertainty between the model and flight test results.

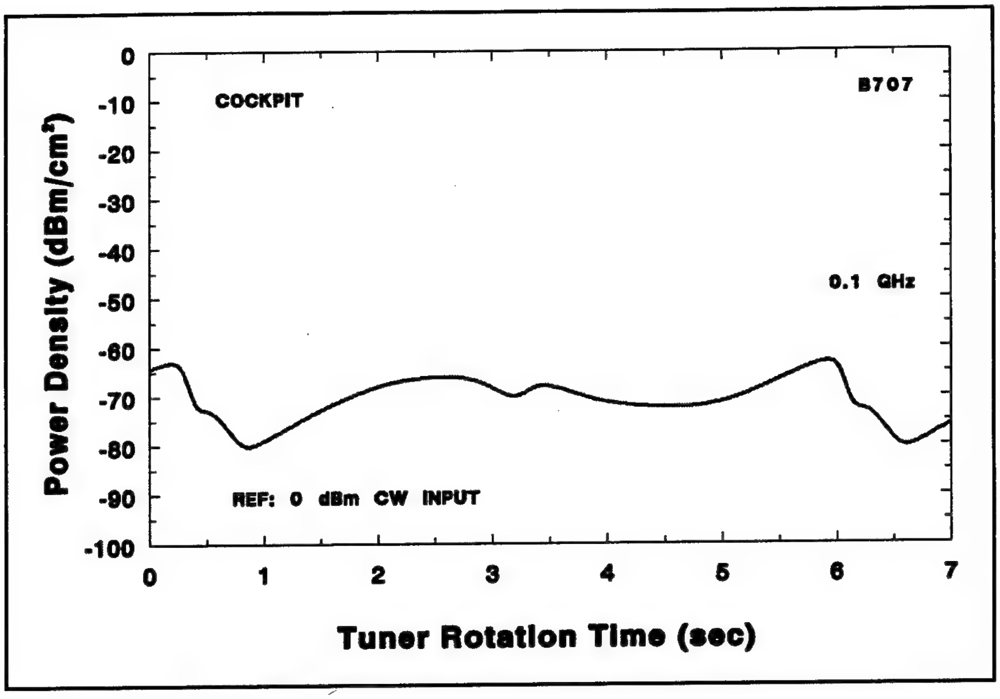

FIGURE 1. B707 STIRRING RATIO DATA AT 0.1 GHz IN COCKPIT

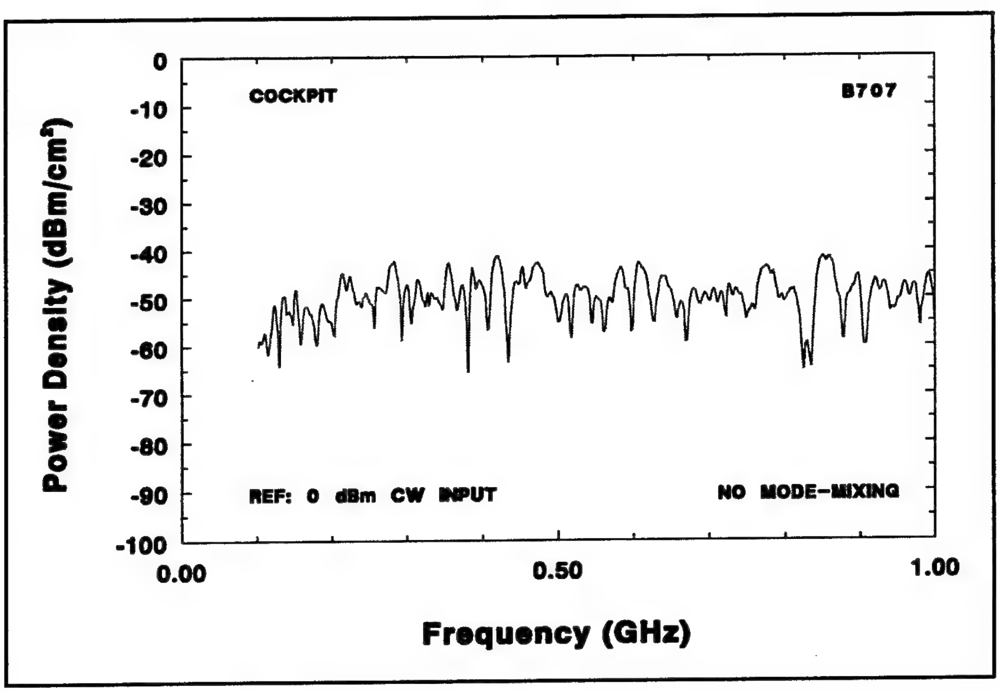

FIGURE 2. B707 COCKPIT LOW FREQUENCY MODAL STRUCTURE DATA

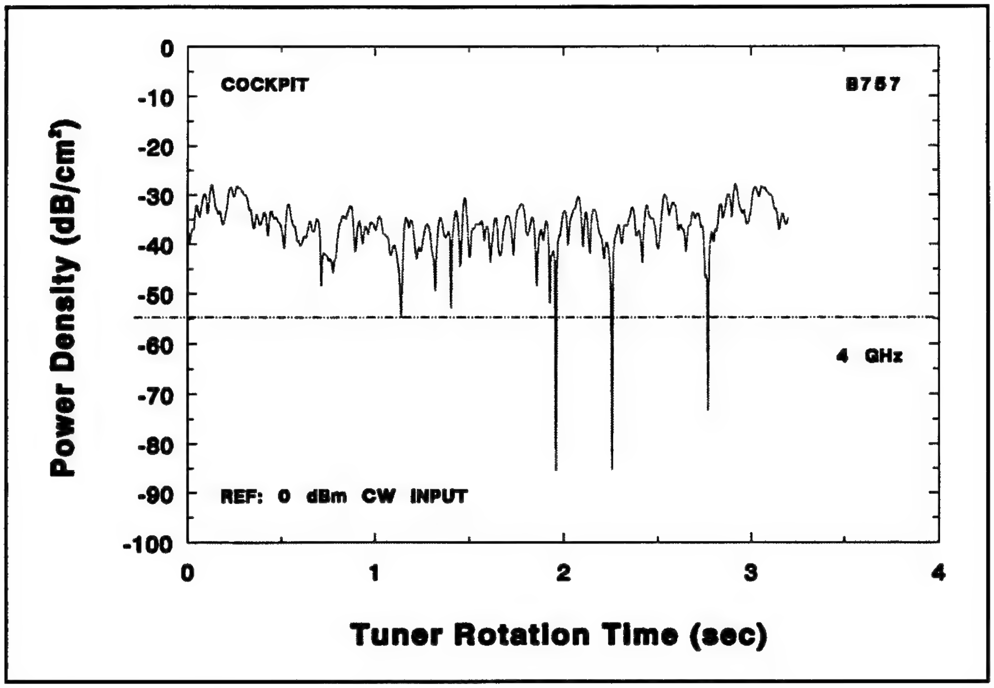

FIGURE 3. B757 STIRRING RATIO DATA AT 4.0 GHz IN COCKPIT

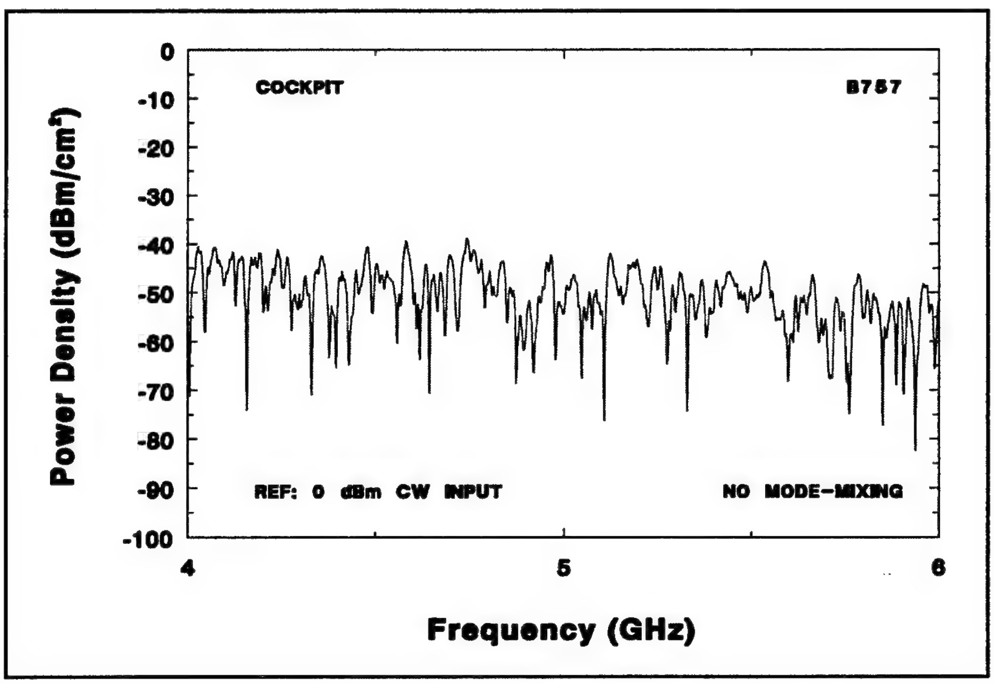

FIGURE 4. B757 COCKPIT HIGH FREQUENCY MODAL STRUCTURE DATA

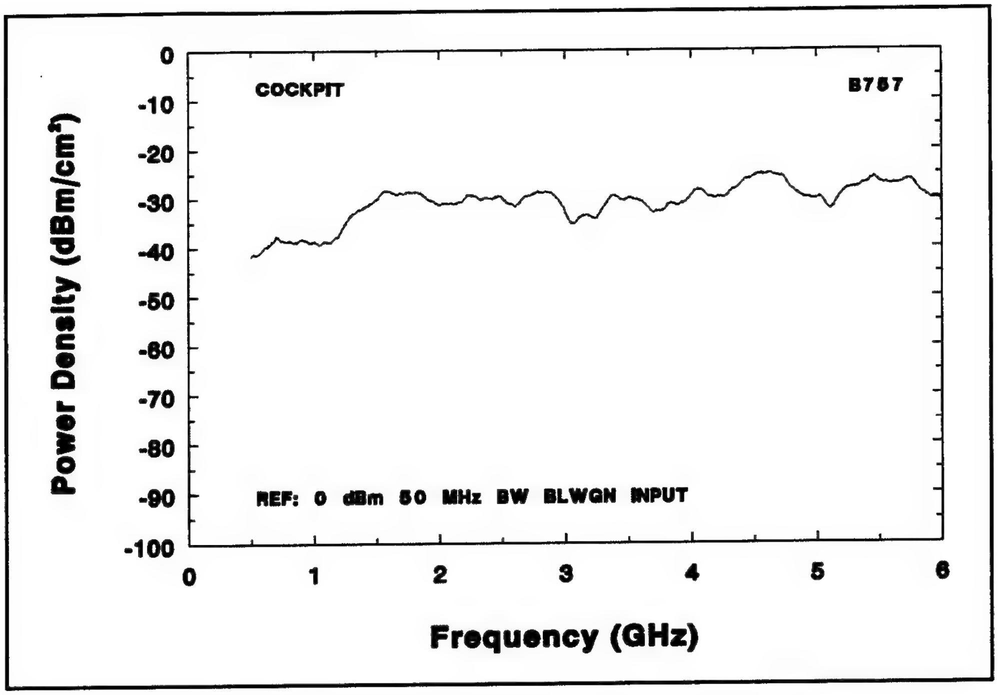

FIGURE 5. B757 COCKPIT INSERTION LOSS DATA

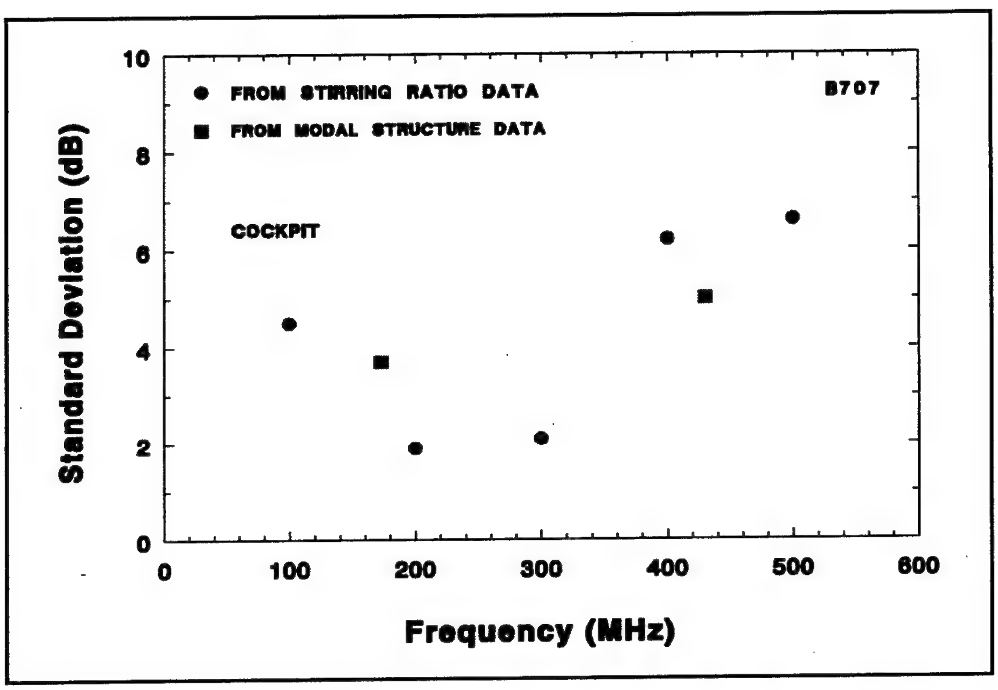

FIGURE 6. B707 COCKPIT LOW FREQUENCY BOUNDARY CONDITION EFFECTS

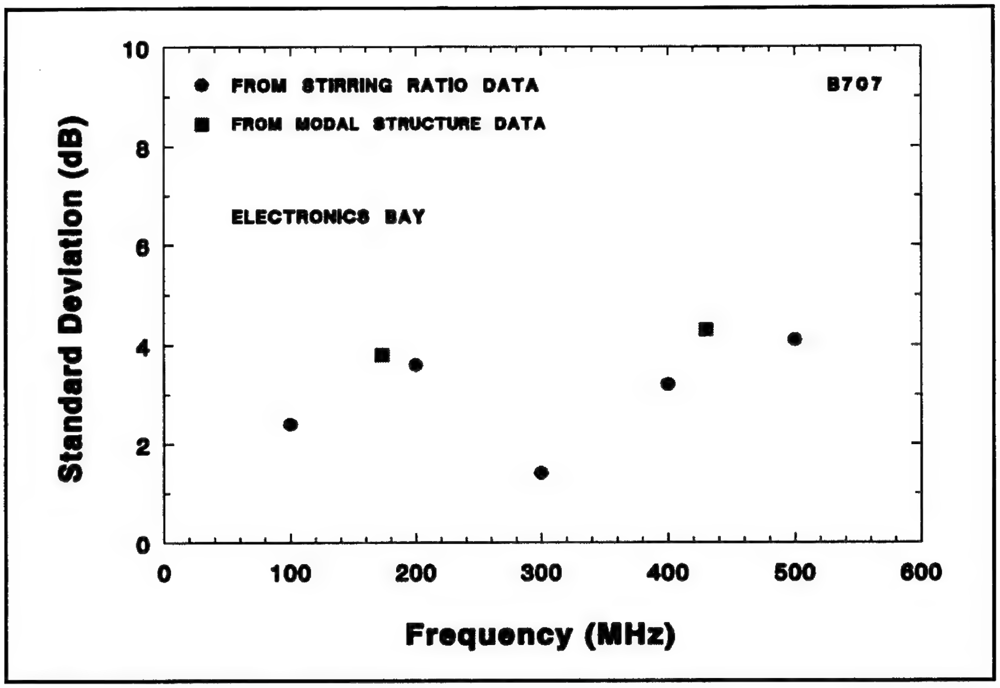

FIGURE 7. B707 ELECTRONICS BAY LOW FREQUENCY BOUNDARY CONDITION EFFECTS

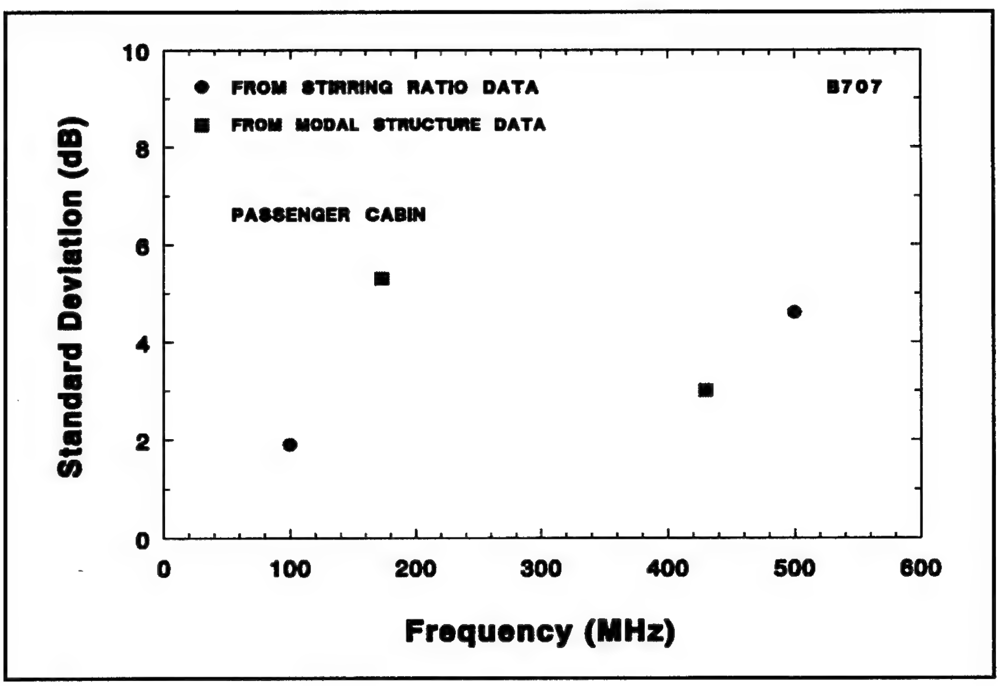

FIGURE 8. B707 PASSENGER CABIN LOW FREQUENCY BOUNDARY CONDITION EFFECTS

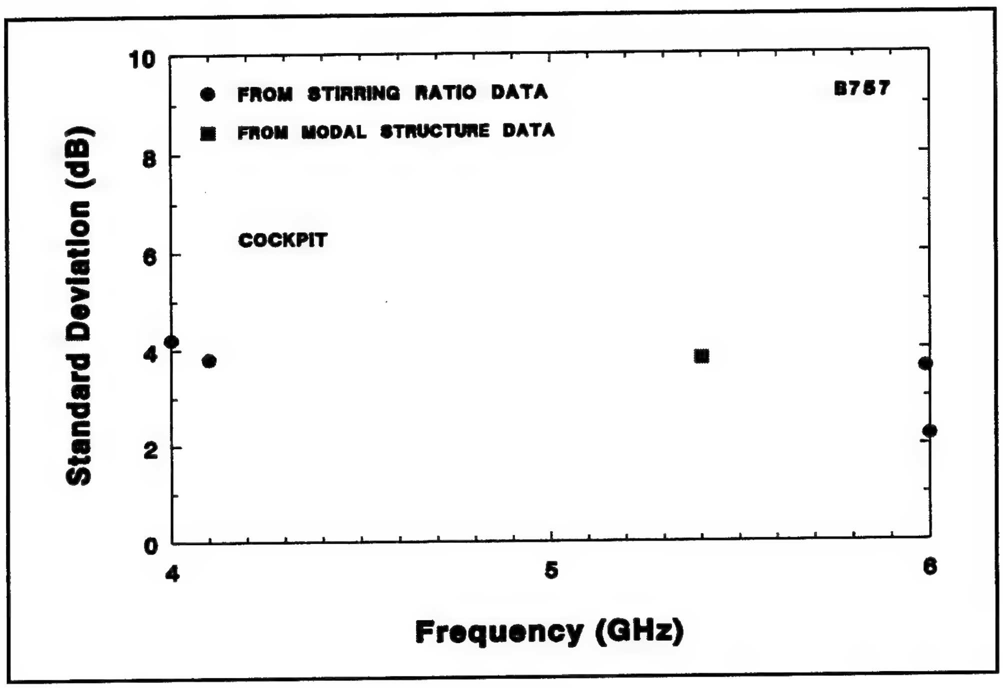

FIGURE 9. B757 COCKPIT HIGH FREQUENCY BOUNDARY CONDITION EFFECTS

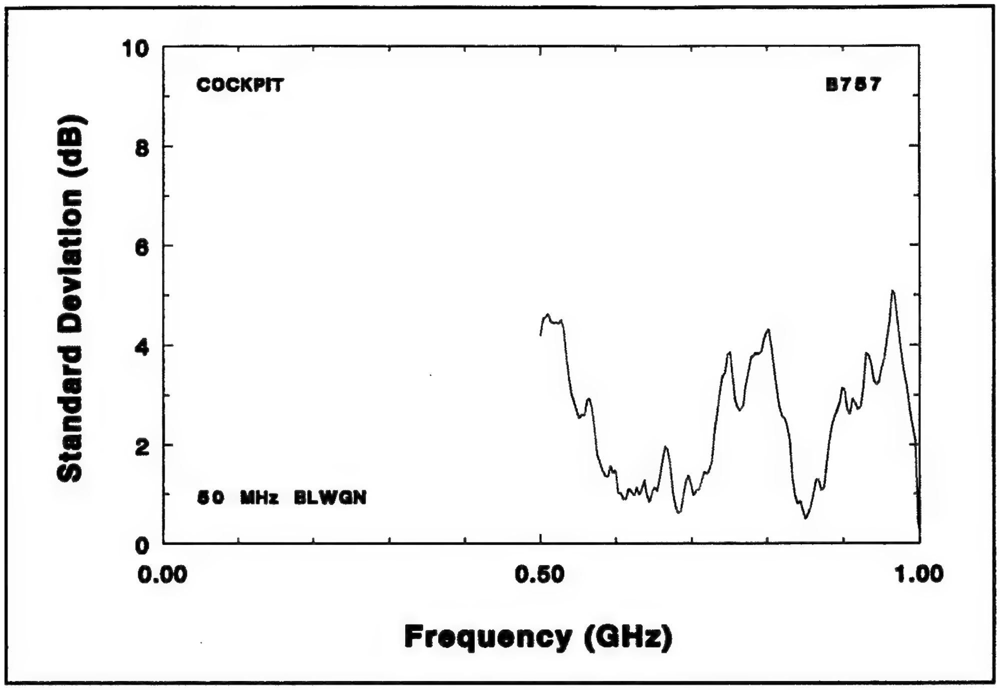

FIGURE 10. B757 COCKPIT LOW FREQUENCY STANDARD DEVIATION DATA

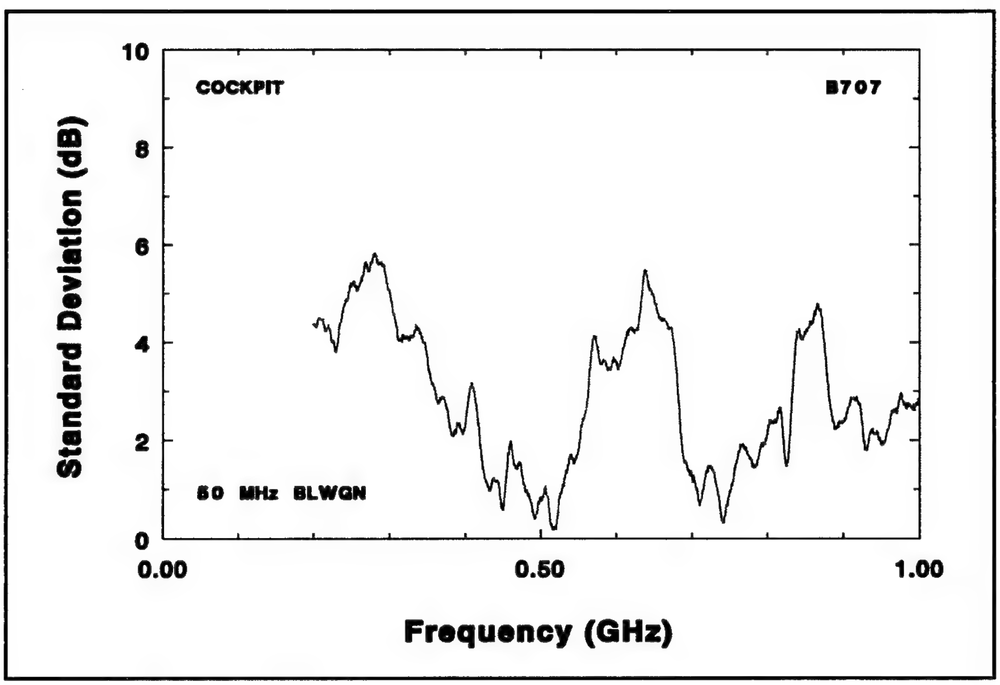

FIGURE 11. B707 COCKPIT LOW FREQUENCY STANDARD DEVIATION DATA

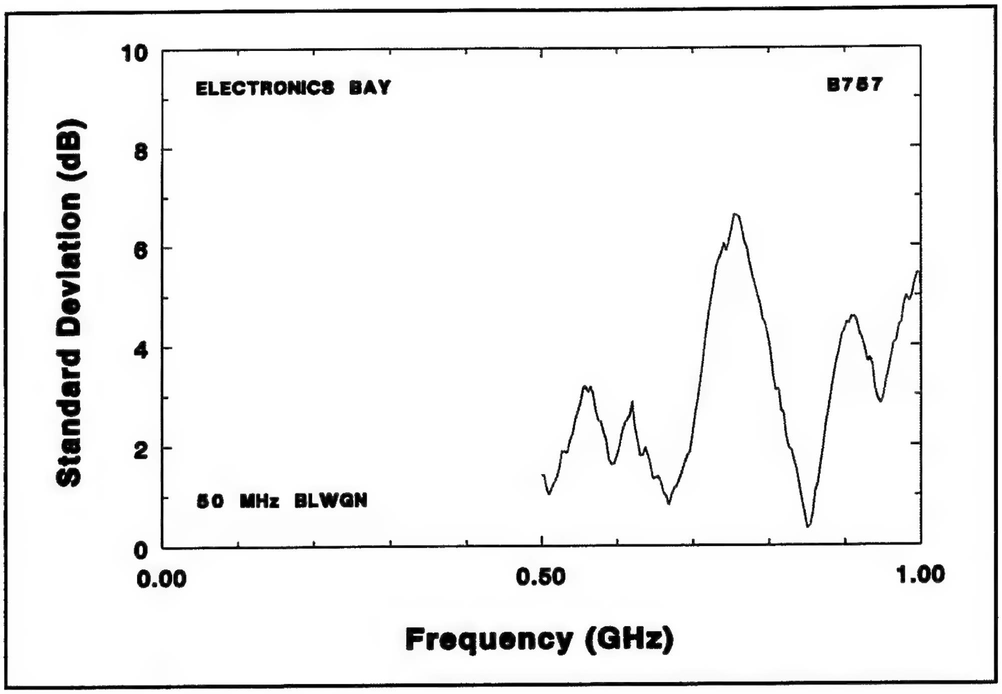

FIGURE 12. B757 ELECTONICS BAY LOW FREQUENCY
STANDARD DEVIATION DATA

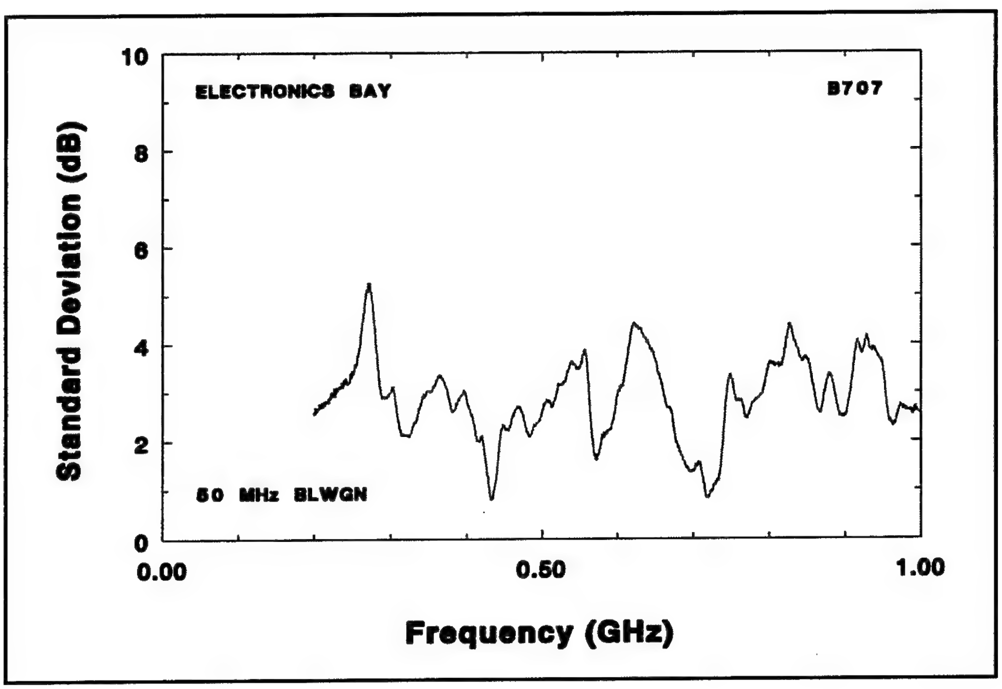

FIGURE 13. B707 ELECTRONICS BAY LOW FREQUENCY
STANDARD DEVIATION DATA

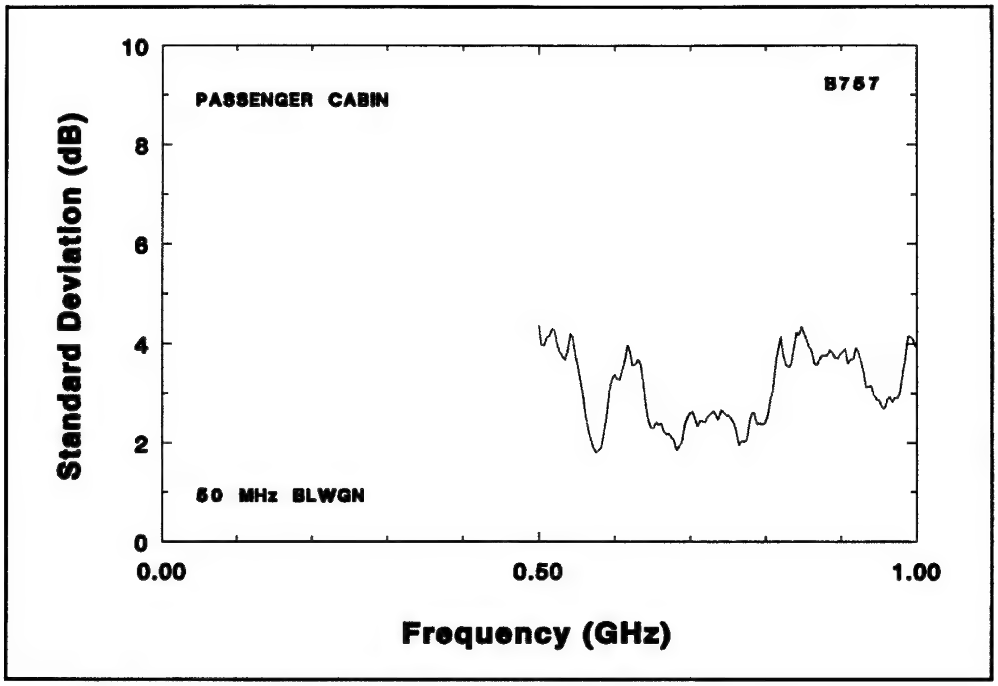

FIGURE 14. B757 PASSENGER CABIN LOW FREQUENCY STANDARD DEVIATION DATA

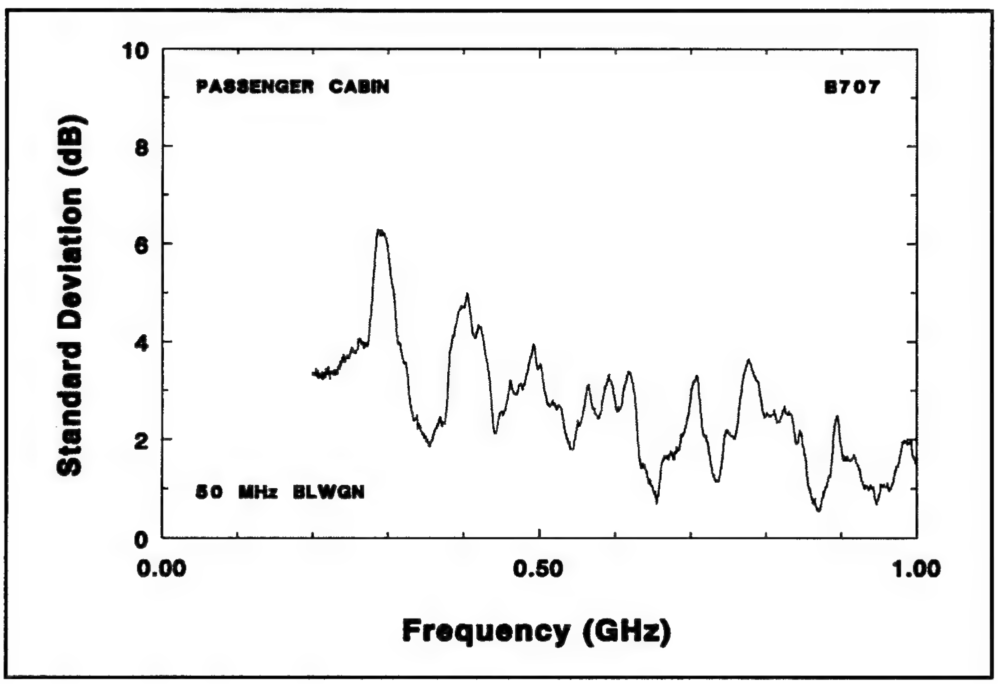

FIGURE 15. B707 PASSENGER CABIN LOW FREQUENCY STANDARD DEVIATION DATA

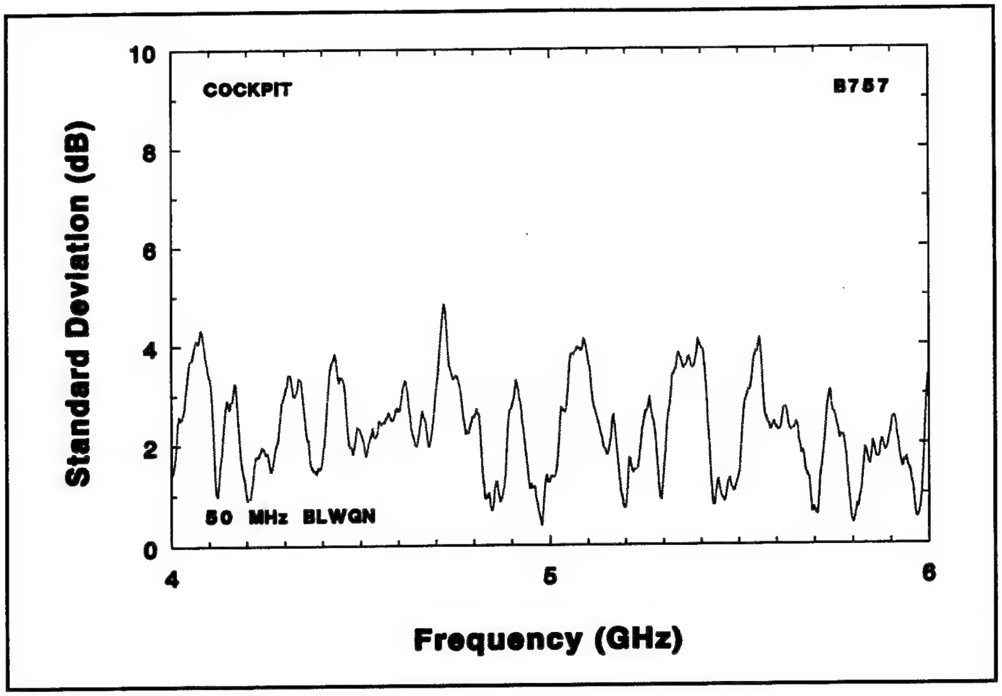

FIGURE 16. B757 COCKPIT HIGH FREQUENCY STANDARD DEVIATION DATA

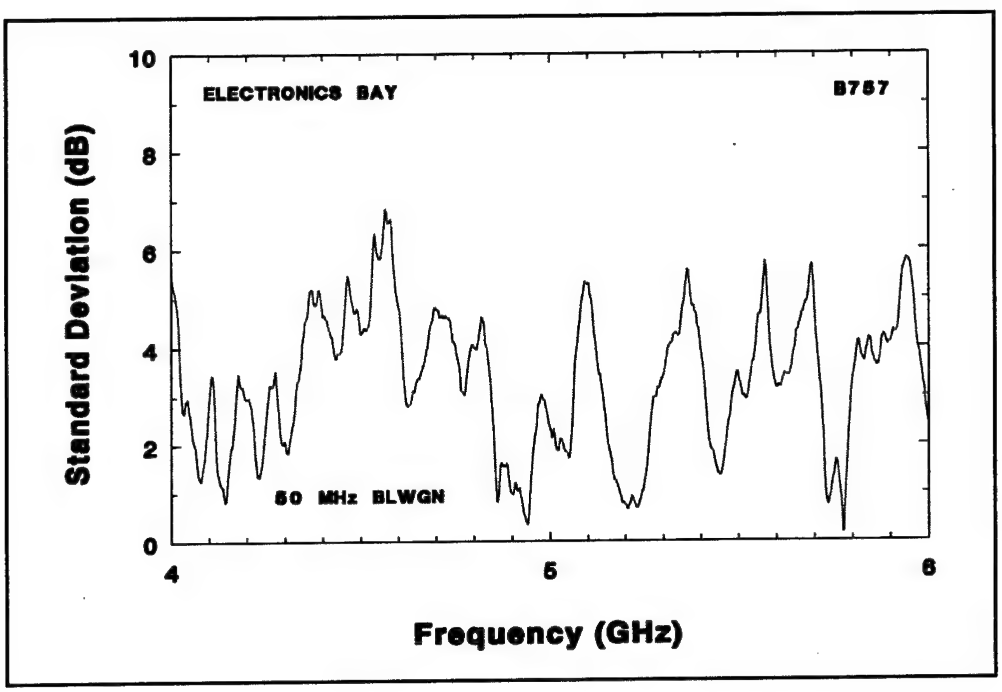

FIGURE 17. B757 ELECTRONICS BAY HIGH FREQUENCY
STANDARD DEVIATION DATA

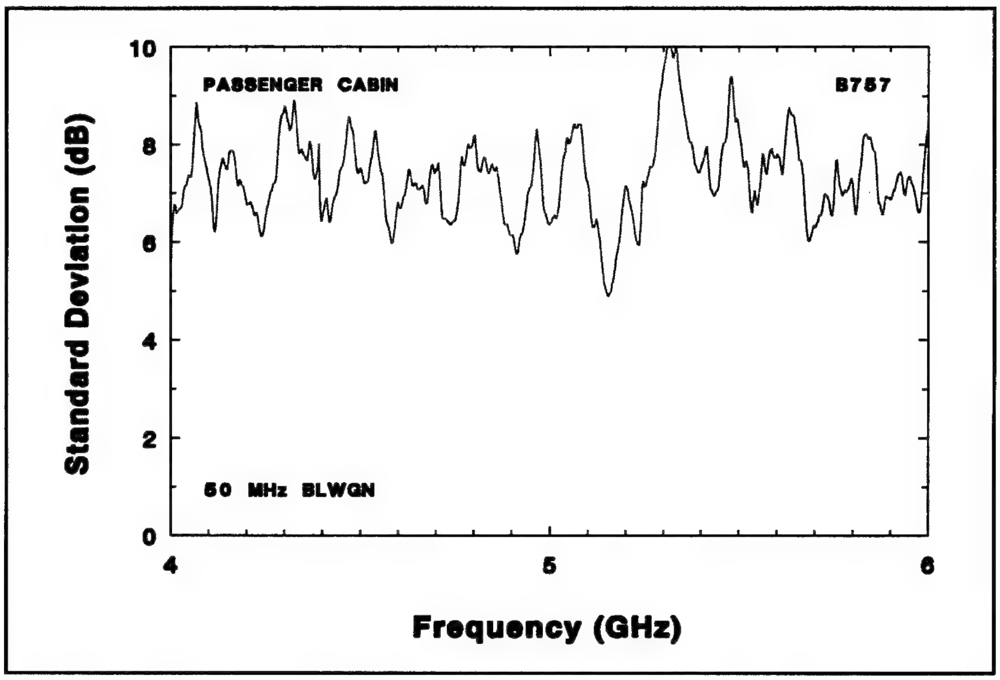

FIGURE 18. B757 PASSENGER CABIN HIGH FREQUENCY STANDARD DEVIATION DATA

TABLE 1. STANDARD DEVIATION FOR BOUNDARY CONDITION EFFECTS

BOEING 757 ESTIMATED STANDARD DEVIATION (dB) FOR BOUNDARY CONDITION EFFECTS			
CAVITY	0.173 GHz	0.430 GHz	5.4 GHz
COCKPIT	3.7	5.0	3.8
E. BAY	3.8	4.3	4.9
CABIN	5.3	3.7	4.5

TABLE 2. STANDARD DEVIATION FOR MEASUREMENT LOCATION EFFECTS

BOEING 757 ESTIMATED STANDARD DEVIATION (dB) FOR MEASUREMENT LOCATION EFFECTS						
	0.173 GHz		0.430 GHz		5.4 GHz	
CAVITY	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM
COCKPIT	4	6	3	5	2.5	5
E. BAY	3	6	2	4	3	6
CABIN	4	6	3	4	5.8	10

TABLE 3. TOTAL STANDARD DEVIATION FOR FIELD VARIABILITY

BOEING 757 ESTIMATED STANDARD DEVIATION (dB) FOR TOTAL FIELD VARIABILITY						
	0.173 GHz		0.430 GHz		5.4 GHz	
CAVITY	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM
COCKPIT	5.5	7.0	5.8	7.1	4.5	6.3
E. BAY	4.8	7.1	4.7	5.8	5.7	7.7
CABIN	6.6	8.0	4.8	5.4	7.3	11.0

REFERENCES

1. Hatfield, M. O.; Freyer, G. J.; Johnson, D. M.; and Farthing, C. L., *Demonstration Test of the Electromagnetic Reverberation Characteristics of a Transport Size Aircraft*, Naval Surface Warfare Center, Dahlgren Division, Dahlgren, VA, Report No. NSWCDD/TR-93/339, Jul 1994.

2. Loughry, T. A., *Frequency Stirring: An Alternative Approach to Mechanical Mode-Stirring for the Conduct of Electromagnetic Susceptibility Testing*, USAF Phillips Laboratory, Kirtland AFB, NM, PL-TR-91-1036, Nov 1991.

3. Hatfield, M. O.; Loughry, T. A.; Ondrejka, A. R.; Johnk, R. T.; Freyer, G. J.; Johnson, D. M.; and Slocum, M. B., *Phase II Demonstration Test of the Electromagnetic Reverberation Characteristics of a Large Transport Aircraft*, Naval Surface Warfare Center, Dahlgren Division, Dahlgren, VA, Report No. NSWCDD/TR-97/84, in process.

APPENDIX A

EFFECTIVE MODAL STRUCTURE

The modes in a cavity are determined by the boundary conditions. For a rectangular cavity of dimensions L (length), W (width), and H (height), the mode frequencies can be shown to be[1]

$$F_{l,m,n} = 150\,((l/L)^2 + (m/W)^2 + (n/H)^2)^{0.5}$$

where l, m, and n are the mode indices.

Figure A-1 shows a hypothetical mode distribution as a function of frequency. Each mode represents a unique field variation (modal structure) as a function of spatial location throughout the cavity.

The cavity quality factor bandwidth, BW_Q, is defined as F/Q at the 3 dB points of a guassian distribution. A representative BW_Q is shown at F_o in Figure A-2. In this case, only one mode is excited when the cavity is driven at F_o. The effective modal structure at F_o would be that of the $F_{l,m,n} = F_o$ mode.

Figure A-3 shows the effects of an increased BW_Q. In this case, three additional modes can be excited when the cavity is driven at F_o. The effective modal structure would be the vector sum of the four modes with different amplitudes. The spatial field variation will be different than that obtained from the single F_o mode. Thus the effective modal structure can be changed by varying the cavity Q.

Figure A-4 shows how the effective modal structure can be impacted by the theoretical mode density which, at a specific frequency, depends on the cavity size. The increased mode density yields additional modes for the same BW_Q as in Figure A-3. In this case the field variation will be based on the vector sum of seven modes when the cavity is driven at F_o. Current theory suggests that an overmoded condition implies the cavity has ten or more modes within the BW_Q.

In summary, the effective modal structure depends on both the theoretical mode density and the quality factor bandwidth at the frequency of interest.

[1] Crawford, M.L. and Koepke, G.H., "Design, Evaluation, and Use of a Reverberation Chamber for Performing Electromagnetic Susceptibility/Vulnerability Measurements", NBS Technical Note 1092, April 1986.

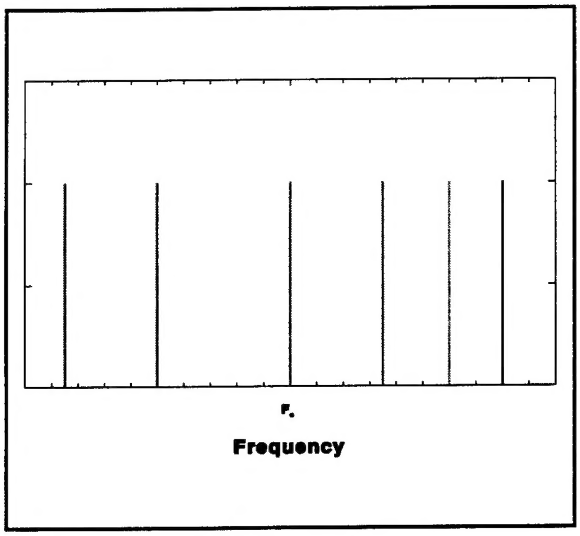

FIGURE A-1. HYPOTHETICAL CAVITY MODE STRUCTURE

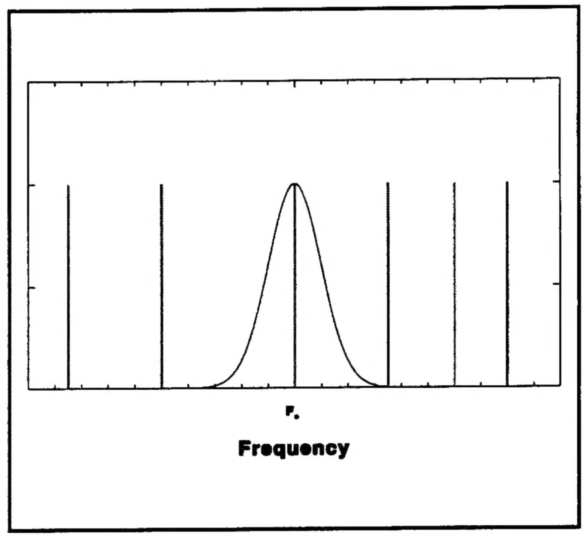

FIGURE A-2. HYPOTHETICAL MODE STRUCTURE WITH QUALITY FACTOR BANDWIDTH

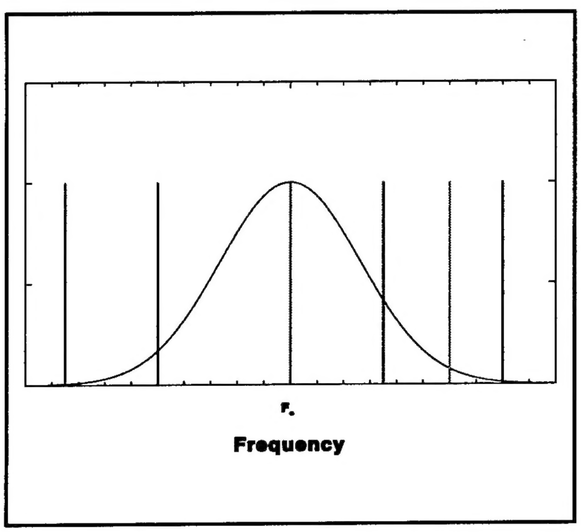

FIGURE A-3. HYPOTHETICAL MODE STRUCTURE WITH LARGER QUALITY FACTOR BANDWIDTH

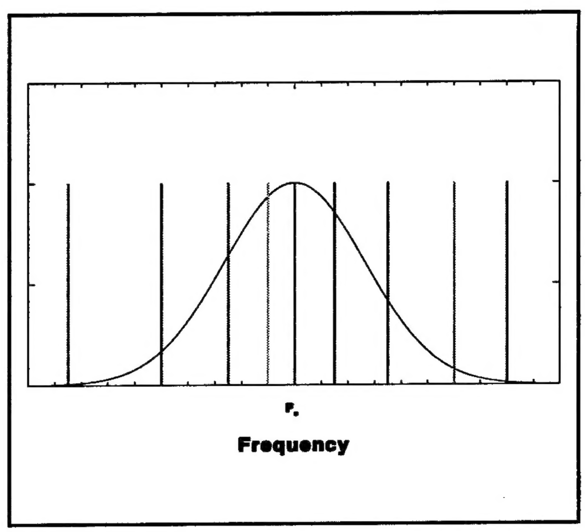

FIGURE A-4. HYPOTHETICAL HIGHER MODE DENSITY WITH LARGER QUALITY FACTOR BANDWIDTH

DISTRIBUTION

	Copies
DOD ACTIVITIES (CONUS)	
ATTN CODE A76	
(TECHNICAL LIBRARY)	1
COMMANDING OFFICER	
CSSDD NSWC	
6703 W HIGHWAY 98	
PANAMA CITY FL 32407-7001	
DEFENSE TECH INFORMATION CTR	
8725 JOHN J KINGMAN RD	
SUITE 0944	
FORT BELVOIR VA 22060-6218	2
NON-DOD ACTIVITIES (CONUS)	
THE CNA CORPORATION	
P O BOX 16268	
ALEXANDRIA VA 22302-0268	1
ATTN K J MOELLER (MS 490)	5
8 NORTH DRYDEN ST	
NASA LANGLEY RESEARCH CENTER	
HAMPTON VA 23681-0001	
INTERNAL	
B60 (TECHNICAL LIBRARY)	3
J52 (FREYER)	5
J52 (HATFIELD)	50
J52 (JOHNSON)	5